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REDUCING POORLY STREAMLINED BODY WATER RESISTANCE BY USING ACTIVE BOUNDARY LAYER CONTROL DEVICES

ЗНИЖЕННЯ ОПОРУ ВОДИ РУХУ ПОГАНО ОБТІЧНОГО ТІЛА ЗА ДОПОМОГОЮ ПРИСТРОЇВ АКТИВНОГО КЕРУВАННЯ ПРИКОРДОННИМ ШАРОМ

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Abstract. It is proposed to install on the wetted surface of the poorly streamlined body: on one a profiled recess, and on the second step. The first device changes the pressure distribution on the surface of the selected object. In the middle recess, a vortex motion is created, in the middle of which the pressure is lowered, which makes it possible to reduce the thickness of the boundary layer. The main purpose of the second device is to reduce the suction effect of water during acceleration of the object. Thus, the resistance force decreases, which means that it is much easier and faster to pick up speed and maintain it for a long time. After studying two methods of reducing resistance, it is proposed to evaluate the effectiveness and the prospect of using the above methods simultaneously with the air lubrication method. The Air Lubrication technology is based on blowing air bubbles out under the hull of the vessel. The air bubble distribution across the hull surface reduces the resistance creating a sublayer between the body of the object and water. These studies were conducted in the Flow Vision software package to obtain visualization and calculations, which confirm that the use of the proposed methods makes it possible to reduce the resistance of the body when it is moved in a liquid.

Key words: recess, boundary layer, resistance, pressure, poorly streamlined body.

Анотація. Вплив течії – складна проблема гідродинаміки, багато аспектів якої ще не повністю вивчені. Турбулентний стан течії призводить до великих сил тертя, тим самим до збільшення використаної енергії. Тому дослідження методів впливу на характер течії є важливим у таких галузях, як кораблебудування, для економії використання енергетичних ресурсів. Об'єктом дослідження є поверхня погано обтічного тіла. У роботі досліджені питання про ступінь ефективності одночасного використання декількох способів активного впливу на пограничний шар спрямованих на зниження опору тіл під час їх руху в рідині. За використання методу повітряного мастила отриманий ефект досягається за рахунок зменшення опору тертя тієї частини поверхні корпусу, яка покривається повітряним прошарком. Для зменшення повного опору можуть бути використані виїмки за умови правильного вибору місця розташування і їх параметрів форми. Установка сходинки на днищевій поверхні об'єкта порушує плавність обводів, сприяючи вихороутворенню, у разі збільшення швидкості ходу по воді інтенсивність вихороутворення зростає, тим самим змінюючи характер течії рідини. Твердотільні моделі із встановленими засобами створювалися в CAD системі Solid Works. Розрахунки проводилися в програмному комплексі Flow Vision у два етапи. У першому етапі досліджувалося погано обтічне тіло зі сходинкою і виїмкою. На другому етапі досліджувалися ті ж тіла з подачею мастила і зі сходинки і з виїмки.

Ключові слова: виїмки, прикордонний шар, опір, тиск, погано обтічне тіло.

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Formulation of the problem. One of the promising methods of reducing the vessels resistance is the creation of air lubrication on the bottom surface of their hulls. This method makes it possible to reduce the friction resistance significantly, as well as the wave resistance can be reduced by reducing the pressure gradient in the stream along the vessel's hull. Stern profiled recess are also one of the methods of active influence on the boundary layer. With the right choice of dimensions and their location, they will affect the thickness of the boundary layer, as well as contribute to the redistribution of pressure on the surface of the ship's hull.

Analysis of recent researches and publications. An analysis of existing publications on the main trends in the development of methods for impact on the boundary layer showed that, in an effort to reduce fuel costs, more and more research is being carried out that aims to reduce the resistance of the ship to the liquid. It is possible to perfect the shape of a ship only to a certain point, which is already close and can not be surpassed. The fact is that even the perfectly streamlined body during movement causes the formation of waves and feels the resistance to water friction on its lining. Today, active research is being carried out and the fluids are used which allow to improve the stability of the vessel on the go, to damp rolling and pitching, to lower the wetted surface of the hull, and, consequently, resistance to the vessel movement, which is demonstrated in studies [1; 2]. In paper [3] received a positive answer to the question of the possibility of creating effective artificial caverns on the bottom of planing vessels, the speed of which corresponds to Froude numbers exceeding 4, as well as obtaining experimental data on the hydrodynamic characteristics of planing vessels with artificial cavities at the bottom, estimated speed of the lying in the range from 3.5 to 5.5. The experiments to generate air layers on the lower surface of a flat plate in the large water tunnel were conducted, which is demonstrated in studies [4]. After that, resistance and self-propulsion tests for a 66K DWT bulk carrier were carried out in the towing tank of SSMB to estimate the expected net power savings. The subject of paper [5] is the steady hydrodynamic modeling of semi-planing air-cavity hulls. Parametric calculations are presented for a stepped hull with pressurized and open cavities, illustrating the influence of the step height and Froude number. The system of air-lubricating the body of the vessel was interested in the Marine Institute's Irish Science and Technology Center, Japanese company Mitsubishi Heavy Industries, scientists from the Dutch shipbuilding group Damen Shipyards, which shows the constant development in this direction in studies [6; 7; 8].

The purpose of the paper. The purpose of this article is to study the efficiency of the recess in comparison with the method additions lubricants, as well as the effectiveness of their simultaneous use.

Methods, object and subject of research. The subject of the study is a poorly streamlined body, namely a parallelepiped, on the bottom surface of which a step and a recess was established for the study of the effectiveness of methods for reducing body resistance, which is the object of research. The main method of research is to carry out calculations in the CFD package at the first stage under conditions without supply of lubricant to the bottom surface of the body, and the second with the supply of lubricant.

The presentation of the main material. To reduce the friction resistance, promising methods are considered, which influence the boundary layer, since the resistance to friction is the largest fraction of the full resistance of medium and large moderate high-speed vehicles. One such method is the creation of air lubrication (Fig. 1). The idea is to blow the air through special channels to the surface of the body to create a thin air covering of 1–2 cm of thickness, covering the bottom, which reduces the resistance, because the air has 850 times less density than water [9; 10].

For the most part, the complex supply of air is used for water tidal hulls (Fig. 1a); for gliding vessels, the air is fed by one wave (Fig. 1b). More complex systems of air lubrication can be used for complex forms of cases (semi-submersible vessels and others). Below there is a simplified scheme of the case using this method and an underwater photograph of air lubrication under this hull (Fig. 2).

With the Flow Vision software system, the flow of a smooth, poorly streamlined body was initially modelled, which is the primary model with which subsequent results are compared. The next stage was the study of the primary model with the first step, installed on its bottom surface, and then the recess. It should be noted that

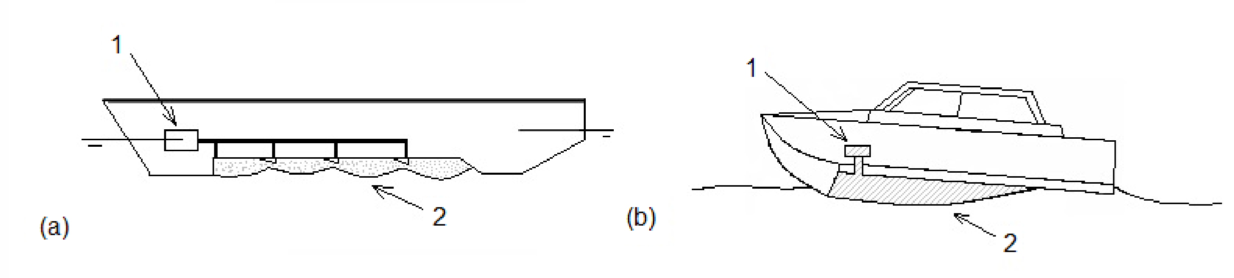

Fig. 1. Types of air lubrication on the bottom surface of the vessel [11]

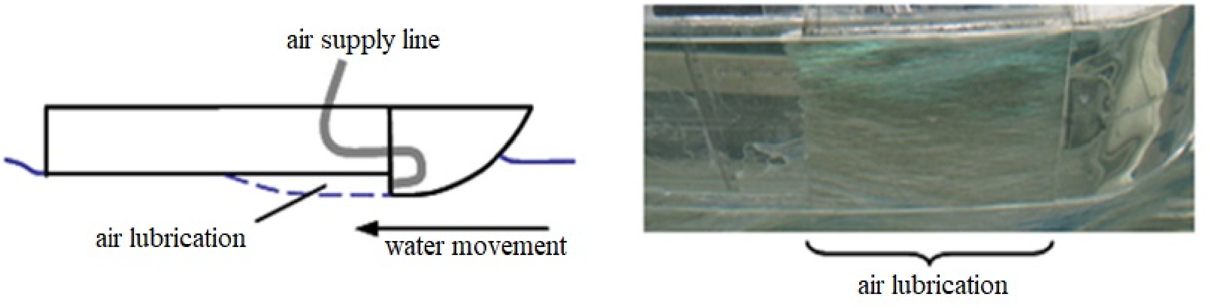

Fig. 2. A simplified scheme of a hull and underwater photograph under this hull [9]

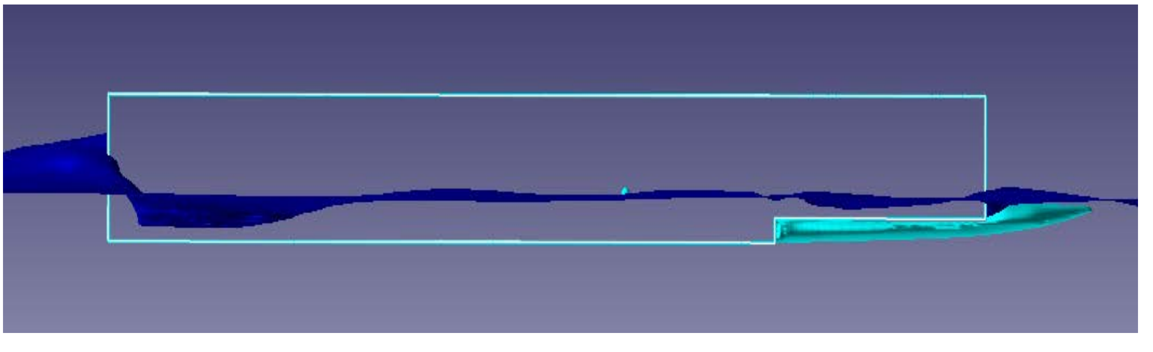

Fig. 3. Visualization of the formation of air oil in a step

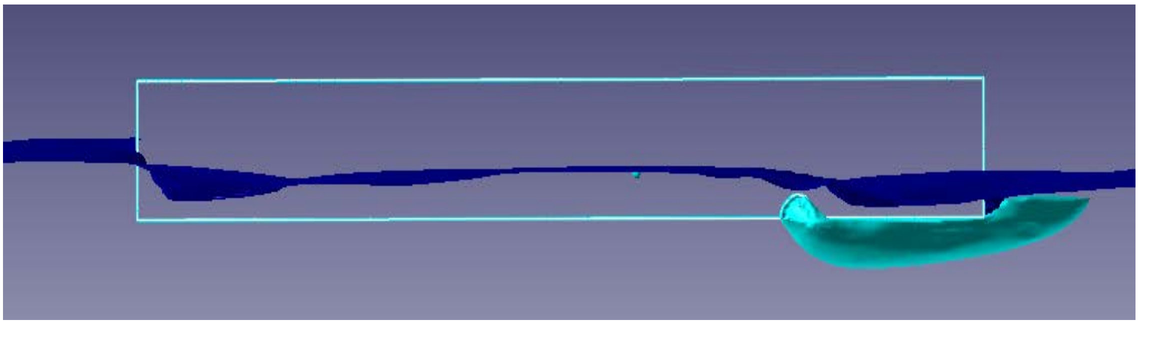

Fig. 4. Visualization of the formation of air lubrication in a step from a profiled recess

Table 1. The results of the study are poorly streamlined body

Speed, [m/s]	A smooth Body, [кН]	A body with a step without a lubrication, [кН]	A body with a recess without a lubrication, [кН]	A body with a step with a lubrication, [кН]	A body with a recess with a lubrication, [кН]
6	18,691	19,511	17,193	17,585	15,347

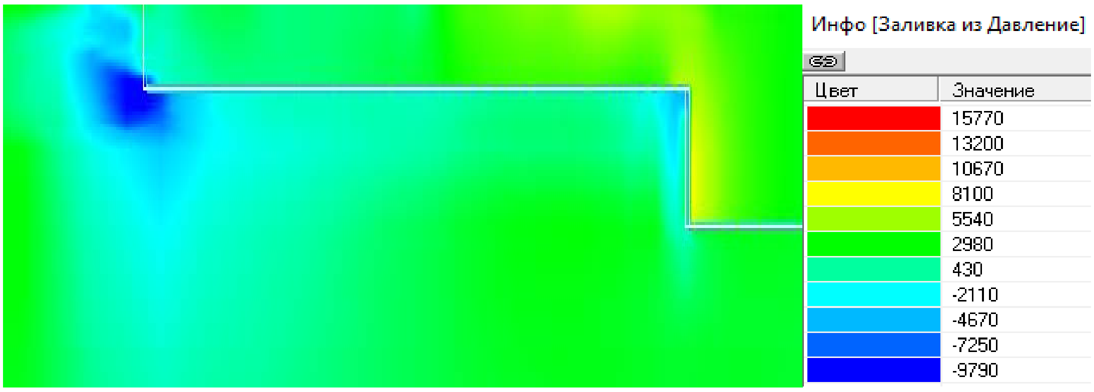

Fig. 5. Visualization of the pressure distribution after the step

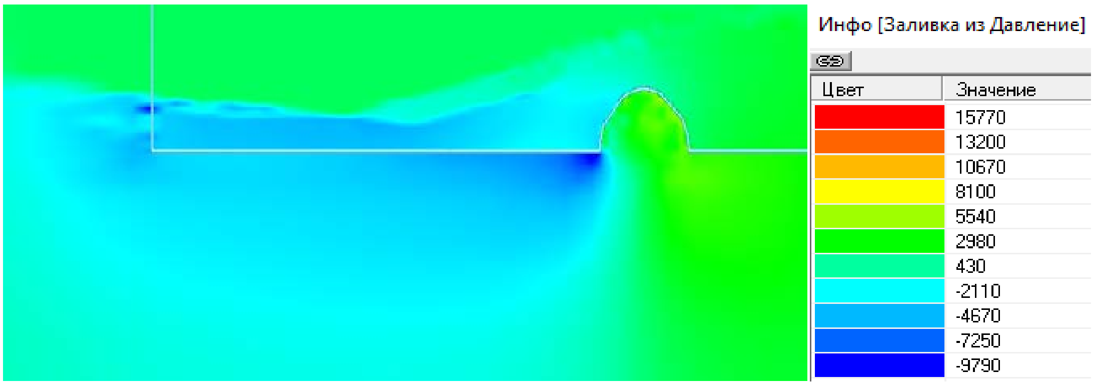

Fig. 6. Visualization of the pressure distribution after the recess

at this stage, the recess showed a better result for a step by 5%. After the results were obtained, the formation of lubrication was simulated in the case of its feeding in a step established on the surface of a poorly streamlined body (Fig. 3).

Further, the formation of lubrication was simulated in the case of feed from a profiled c (Fig. 4).

Based on the calculations, Table 1 was constructed, in which the effect of the step and recess with and without lubrication is shown.

On the received pictures of the pressure distribution visualization, it is observed that on the part where the lubrication was formed in a step and the profile recess and the pressure drops, and the speed is reduced (Fig. 5–6).

Discussion. In the framework of this work, the study of the effectiveness and prospect of simultaneous use of several methods of active influence on the boundary layer has been performed in order to improve the effectiveness of reducing the total body resistance. According to the results, it is confirmed that due to the supply of lubricant, the pattern of pressure distribution and distribution of viscous stresses along the surface of a poorly streamlined body. Calculations have shown that as a result of the simultaneous installation of profiled recess and brushes created from it, the resistance decreased by 15%.

CONCLUSION. In this paper, a combination of several methods for controlling the boundary layer is considered in order to reduce the resistance to the surface of the selected body. According to the task, projects were created in the Flow Vision software system and the calculation of the surface of the poorly streamlined body was performed. A large number of variations were made on the use and combination of selected methods on the surface of a poorly streamlined body. In the future, the effectiveness of using the combination of methods on the bottom surface of the vessel is planned to study.

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